Specification

001 Title of Invention:

Rearing Fly Larvae and Animals in Space for Waste Recycling and Food Supplying

This application is a continuation-in-part of application No. 10/178,344, filed on June 25, 2002.

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U.S. PATENT DOCUMENTS Patent Number: 5,618,574 4/1997 Bunch 426/641

Only one related US Patent-titled "Fish Food" was found in searching of US Patent from Jan.1974 to Nov.2001.

This patent applies dried fly larvae as fish food to improve the growth, feeding efficiency or coloration of fish.

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006 Statement regarding federally sponsored research or development

Not Applicable

007 Incorporation-by-reference of material submitted on a compact disc

Not applicable

008 Background of the Invention

(1) Field of the Invention:

A method of waste recycling for food regeneration in the space.

(2) Background Art:

The scientists in many countries, like China, USSR, USA, Mexico, Eastern Europe, Israel, Australia and Central and South America have studied for rearing maggot in manure digestion, to convert residual protein and other nutrients in animal manures to high quality maggot biomass as animal feedstuff. (reference 1~13).

In US Patent 5,618,574, Bunch discloses to apply dried fly larvae as fish food to improve the growth, feeding efficiency or coloration of fish..

There are no any other discloses about using maggot to recycle human wastes and other wastes in the space, the maggot can be the animal's feedstuff, and the animals will be human's food in the space so far.

009 Brief Summary of the Invention

In this invention we propose rearing one of the maggot - housefly larvae (HFL)as space food source besides crop plants for waste recycling and food production in long term mission. HFL have great vitality and seldom get disease. They can be easily reared with small volume of containers where HFL and feedstuff could closely touch in microgravity under controlled constant temperature and humidity without much care. The feedstuff are composed by mixing of the human/animal wastes (faces, urine; animal dejecta and leftover bits) and cast-off crop (such as wheat bran, bean dregs). The crop is also cultivated as the space food by NASA. Thus the feedstuff nutrition from both human/animals wastes and crop waste can be all recycled to achieve the goal of efficiently producing nourishing HFL. The HFL will be the food source for feeding animals. The water and nutrition left in the residues after rearing HFL can be recycled and fertilized the crop plant again. Besides, current self-supported space food - the crop plant, such as wheat, potato, bean mainly offer most calories and plant protein necessary for human body. They can not offer some other adequate nutrients such as animal protein, fatty acids, amino acids and so on. HFL body consists of rich protein, 18 kinds of

amino acids (thereinto 10 kinds are necessary to human body), fatty acids and many kinds of vitamins, minerals, electrolytes. The alive HFL and the powder of HFL will be the ideal feedstuff for animals, such as the poultry, aquatics, amphibian and livestock. These animal bodies combined with their eggs will be varied ideal food – they are all meat diets for human in the space. Fly eggs have very strong reproduction and growth ability.

Their reproduction and growth cycle are very short. They usually get mature in 4 days after being hatched, and their weight increase by 250~300 times. The frozen maggot eggs have long life and keep with their reproduction ability. For 5 crew in 10 years mission, around 25 kg fly eggs could be brought from earth at the beginning for food source without delivery again. Rearing maggot and animals combined with crop plants in the space would be a regenerative integrated system with close loops of food, water, air recovery from most wastes. The operations of rearing maggot are all under the restrictions of minimum volume, mass, energy and labor. It is an efficient, reliable and effective bioregenerative system in long term mission.

010 Brief Description of the several views of the drawing(s):

Not applicable.

011 Sequence Listing:

Not applicable.

012 Detailed Description of the Invention

The current problem and way of solving the problem:

Up to date, all crewed space missions were short-term and in low earth orbit. They have relied on food resupply from earth. The wastes have to be discarded or stored after returning to earth. But for future long-term mission and permanent planetary bases on such as moon and Mars, the earth supplying mode will become impossible. The recovery and recycling of nutrients from wastes to support food production have to be done in space, however, current technology cannot support this goal. The NASA's crop plant-based bioregenerative systems provide only a fraction of the total waste recycling (mainly CO_2 and gray water) and food requirement, it also requires high level of light energy for maximum photosynthesis, large growing area and long growing period. So current NASA's Advanced Life Support technology cannot provide life support functions for long term human exploration in a cost-effective manner.

Here we propose rearing one of the maggot - housefly larvae as space food source besides crop plants for waste recycling and food production in long term mission.

As we know, the maggot readily feed on fresh manure, to convert residual protein and other nutrients in to biomass, which is a high quality animal feedstuff with rich protein and other nutrients. The fly eggs can be offered with minimum capacity in long term mission by freezing them in liquid nitrogen, and can be hatched and reared by warming them any time. Maggot is fly larvae (FL), the scientific name of housefly (HF) is Musca Domestica. We select Housefly Larvae (HFL) as first candidate in our invention, this is because, HFL have strong reproduction ability, short life cycle, seldom get disease, and are easily reared in high density, high efficiency without much care. It is well known by a great deal studies, HFL have the ability to flourish in virtually any animal manure (certainly human manure too). They can convert these waste to high quality nourishing animal feedstuff without poison.. The equipment and operation for them are simple. Also, feeding, processing, storage of HFL, and using HFL as feedstuff for varied animals are all the mature technique on the ground. It may easier to transfer to space usage with less time and investment.

We do not select HF pupae as first candidate even if pupae contain rich nutrition too and with the preferable stage for easy harvest. The reason is loss of biomass in pupal development. Pupae are about half weight of the mature maggot and more chitinous exoskeleton of the adult may reduce nutrient availability.

HF has fabulous reproduction speed. A couple of HF can produce around 1000 eggs during its reproduction period (12-15 days). Theoretically, 1000 eggs can reproduce 200 billion adult HFL within four months. 200 billion HFL contain more than 600 ton pure protein. The egg usually takes 4 days to become mature HFL and 10 days to fly. It has short and speedy reproduction period with high output. The weight of one HF egg is around 0.08mg (one gram of HF eggs contains 12000-14000 eggs)[20], the weight of one adult maggot will be 20~30 mg, which is 250~350 times after being reared for 4 days. It is second for none to produce animal protein so far. Moreover, rearing HFL in the darkness and aeration room with temperatures of 25-28℃ and comparative humidity 60-80 %, can reproduce continuously generation by generation. HFL are light avoiding insects, so they should be reared in dark container instead of in light for plants photosynthesis.

Nutrition content of HFL

The data indicating below is from four national academic institutes in China.[16],[17], [18],[22].

The Analysis Results of HFL's Nutrition

The HFL powder is dried from fresh HFL. Its weight is around 1/3 of fresh HFL. HFL powder contains

54-63% of protein which is more than that of fishmeal powder. The fat accounts for 11-17% with similar composing of plant oil or fish liver oil. Amino acids are well combined with 9 kinds essential amino acids for human. The total amount of essential amino acids crucial to human lives is 2.3 times that of fishmeal, the storage of lysine, methionine and phenylalanine are 2.6, 2.7 and 2.9 times that of fishmeal respectively. Two of the essential amino acids, lysine and tryptophan, are poorly in most plant proteins. The essential amino acids account for 43~47%(E%), is more than the referenced standard (40%) issued by FAO/WHO. Essential amino acids/ non-essential (E/N) is 0.70-0.89, which is much more than the referenced standard (60%) issued by FAO/WHO[20]. HFL powder contains rich K, Na, Ca, Mg, P and a lot of trace elements necessary for human such as Zn, Fe, Mn, Cu, B, P, Gr, Co, Al, Si, etc,.also contains sufficient vitamin A, D and B. The content of vitamin D is similar with fish-liver. It especially contains rich B_1 and B_{12} that are insufficient in the crop. B_1 and B_2 are respectively 15 and 1800 times that of milk [21].

Table 1 Nutrition contents of HFL powder, HFL protein powder and fishmeal (%)

	HFL powder			HFL protein powder	Fishmeal
Content \ Data From Ref.	[22]	[18]	[17]	[18]	[16]
Protein	60.88	54.47	62.70	73.03	38.6-61.6
Carbohydrate		12.04		0	2.80
Fat	17.1	11.60	11.20	23.10	1.2
Gross Fiber		5.70		0	19.41
Ash Content	9.2	11.43	10.42	1.83	20
Moisture Content		5.80	5.10	3.34	11.40-13.50
Chitin			3.97		

HFL protein powder is enriched from HFL powder processed with method of acid deposition.

Table 2 HFL Fatty acid

Contains of Fatty acid (g/100g)			
Data From Ref. (17)			
Myristic acid	2.2	Linoleic acid	32.5
Palmitic acid	19.7	Linolenic acid	3.3
Stearic acid	2.3	Saturated fatty acid	27.4
Palmitoleic acid	12.7	Unsaturated fatty acid	68.2
Oleic acid	18.2	Essential fatty acid	36.0

The above table indicate non-saturated fatty acid of HFL powder account for 68.2% of total amount of fatty acid. Thereinto essential fatty acid account for 36% (Mainly Linoleic acid). Plant oil contains much more Linoleic and Linolenic acid with richer nutrition than those of animal. HFL belong to animality, but it contains much more essential fatty acid than peanut oil and vegetable seed oil.

Table 3 Amino Acids of HFL powder, HFL Protein powder and fishmeal（%）

Data From Ref. No.	[22]	[18]	[16]	[17]	[18]	[16]
Amino Acid	**HFL**			**HFL protein**		**Fishmeal**
Aspartic acid		5.4	6.18	9.58	7.60	2.85
Threonine*	2.30	2.39	2.03	4.59	3.17	1.15
Serine		1.83	1.58	4.03	2.57	1.34
Glutamic acid		8.91	8.20	15.06	10.67	5.34
Glycine		2.36	3.84	4.55	2.67	3.27
Alanine		3.64	2.49	6.10	3.21	2.28
Cystine*	0.43	0.31	0.67	1.17	0.50	0.23
Valine*	2.76	2.87	3.23	5.05	3.71	1.58
Methionine*	1.49	1.26	1.25	2.42	2.27	0.46
Isoleucine*	2.34	3.10	2.54	4.21	3.98	1.09
Leucine*	3.57	3.85	4.05	6.92	5.68	2.07
Tyrosine	4.30	3.24	3.22	6.15	5.27	1.37
Phenylalanine*	4.32	3.08	3.51	5.74	4.87	1.19
Lysine*	4.30	4.45	4.30	9.32	4.97	1.64
Arginine		2.18	3.70	5.23	3.88	2.31
Histidine		1.27	1.96	2.91	1.59	0.70
Proline		2.19	4.16	4.08	2.34	2.79
Tryptophan*	0.78			1.10		
E	27.59	24.65	24.80	46.67	34.42	10.78
N		27.68	32.47	51.54	34.62	21.29
E+N		52.33	57.27	98.21	69.04	32.07
E%		47	43	48	49	34
E/N		0.89	0.76	0.90	0.99	0.50

E: Total amount of essential amino acid, N: Total amount of non-essential amino acid.

E%: Percentage of essential amino acid,* E/N: Ratio of essential amino acid and non-essential amino acid.

Table 4 Analysis Result of Several Minerals and Trace Elements in HFL Powder

Mine and elements (PPM)			
Data From Ref. [16]			
K	71.72	Zn	4.40
Na	20.00	Fe	2.33
Mg	26.97	Mn	1.98
Ca	34.12	Cu	0.29
P	62.35	B	0.19

Table 5 Analysis Result of Vitamin Content in HFLs

Contains of Vitamin (mg/100g)			
Data From Ref. [7]			
K	0.35	B1	12.85
A	1.17	B2	28.86
D	1.08	B6	7.83
E	0.45	B12	188.04

Storage of HF eggs and HFL food in space:

1. **Cryopreservation of fly eggs in long duration mission.**

Our invention is to gain nutrient food for the crew by rearing HFL and feeding animals in space. Here we propose the brief operation in space by the section of egg to HFL in normal rearing operation. That means only rearing HFL in stead of fly in the space. Because in space to rear HF will take more room and labor. Therefore there is a need to bring adequate fly eggs from earth for food source storage in long term mission. Fly eggs could become HFL after being hatched. HFL get mature in 4 days and could be animal feedstuff by living HFL or HFL powder.

This concerns technology of frozen HF eggs storage in long term mission to by keeping their strong reproduction and growth ability. With 10 more years research, currently Drosophila (Fruit Fly) eggs could be hatched successfully after reserving under liquid nitrogen. Drosophila egg could grow to fly and keep its reproduction ability. Lynch of Cornell University reported, they can reach 75~90% high hatch rate [14].and Mazur, hatch rate can reach 70~80%[15]. Insect eggs can be recovered by storing in liquid nitrogen with unlimited term as long as keeping egg case in proper permeability before being frozen and controlling warming rate.

Therefore we suppose HF can reach high hatching rate as well as Drosophila because they are all flies.

2. **Amount of HF eggs for storage in long duration mission**

We can bring enough frozen HFL eggs in space while eggs are small size, light weight and easy storage in freeze. They can maintain their reproduction and growth ability in freeze for several decades or hundred years, just as human semen could live that long in freeze. According to our calculation, for every day, each astronaut needs 400g fresh HFL, which is equivalent to 130g HFL powder. It contains around 80g protein (see Table 1), that meets the daily protein need of an adult. There is a need of around 6 gram egg for raising 1.6 kg HFL in 4 days and around 0.5 kg egg for one year. Thus for 5 astronauts in 10 years duration mission, it needs to bring around 25 kg egg from earth. It is an acceptable loading weight in space for food resource in several decades.

3. Storage of food and food source in space

In this food bioregenerative system, as the food (HFL and the feeding animals) is daily produced in space locally, the food storage becomes simple. It is envisioned that these food sources can be usually reproduced by themselves in the space too.

There are two kinds of storage, one is for the storage of those animality foods (animal meat and eggs) and maggot powder. It is the same as on ground for common frozen storage. Another is for those food source storage, such as fly eggs, animal eggs, oosperm and placenta. They can be frozen in liquid nitrogen for cryopreservation in long duration. The technology of frozen storage, and re-warm them in keeping of their strong reproduction and fast growth ability has been basically solved on ground.

These food sources have long life by storing in liquid nitrogen. Theoretically they can be stored with unlimited term and can recover from thaw. There is no need of much care about these food sources during the long-term freeze. They can be taken and unfrozen easily at any time.

HFL rearing and waste recycling in space

The feedstuff for HFL in space is very simple, mainly using human and animal wastes (manure), inedible parts of space animal bodies and crop. HFL readily feed on fresh human waste as its feedstuff, this is because the human waste contains rich nutrition. Most nutrients from all these wastes can be back to crew by taking the food from animals which are fed by HFL.

The residues after rearing HFL is odorless and can be used by crop plant as high grade fertilizer. [2][5][20].

1, The formulation of feedstuff for HFL (weight percent of the feedstuff), is varied on different animals:

Fresh human waste (feces and urine) and Fresh animal waste (manure and animal body residues): 85~90%

Residues of space crop (wheat bran, bean dregs, and pieces of crop stalk/leaf): 10~15%.

2, Processing of the feedstuff before feeding:

Mixing of above composition in a closed container, humidity of the feedstuff in range of 70%$\pm$5% (adjusting by the volume of the urine), temperature in 25-30^{0}C, keeping the feedstuff as fresh as possible.

3, Transplanting of the HF egg on the surface of the feedstuff:

The HFL eggs are token from liquid nitrogen container in ultra low frozen storage, and then warmed for hatching. For suitable density of feeding HFL, 1 kg feedstuff match with 1.0~1.5 gram FL eggs.

4, The conditions for rearing:

There are a serial numbers of same containers for rearing HFL. The number depends on the output needs of the HFL . The containers are all closed for odor control. In the containers: the temperature is 28$\pm$2^{0}C, the

humidity is 70 ±5 %. Installing aeration pipe in both the upper and middle layer for good aeration and oxygen offering, and keeping the aeration speed with 1 grade. The odor flowing in the aeration pipe will be filtrated by the deodorizer. Stirring the feedstuff once a day for avoiding the over hot and short of oxygen internally after placing fly eggs in the feedstuff. Before rearing, the feedstuff and containers should be placed in microwave oven for bactericidal processing. Inside of container be kept in dark with darkness 12:12.

5, The structure of container and rearing procedure:

Each container volume is 40X40X12 CM^3. It is much smaller than that on earth. Because in status of microgravity, HFL and feedstuff have to closely touch in order to keep feeding all the time. Usually, 1 kg mature FHL can be produced within one rearing cycle of 3~3.5 days for each container. The container is divided by three layers with thickness of 8 cm and 2 cm and 2 cm respectively. The upper layer is 8 cm thick for HFL rearing only. It is full of feedstuff. The middle layer with thickness of 2 cm contains wet wheat bran or bean dregs for decontaminating the viscera of the HFL after 3 days rearing. The lower layer with thickness of 2 cm contains wet wood bits or silver sand for making the mature HFL hungry, collecting and cleaning the mature HFL. There are two mesh screens between the three layers. The HFL skin can be cleaned while it goes through the tight screen opening.

The HFL can be driven to middle and lower layers by strong lighting on the surface of the layer and stay in both of the layers for 3~4 hours respectively, then can be collected in lower layer. after 3.5 days of rearing. Do not take 4 days as the collecting time, this is of consideration of the maximum biomass harvest of the HFL to prevent any HFL from becoming pupa. After rearing HFL, all the residue which consist of the water and useful contents can be recycled as fertilizer for space crop plants.

Rearing HF in space.

The fly rearing and reproduction could be a standby way for sudden case in long term mission. Moreover, it is easier to rear HFL than HF in space, so a great deal of breeding space, labor and expense for rearing fly can be saved. In normal situation there is no need to rear HF in long term mission because the problem of storage of HF eggs has been solved. But in contingency of losing some eggs, the crew have to rear HF for complement of losing eggs. Therefore the technology of rearing HF should be reserved. Rearing HF in space shall be as following points

1, Rearing quantity and density:. The rearing density of HFL on the ground in large scale is 40000-60000/m3, but in space the crew only need to rear a small number of flies for egg collection only, to rear fly in the cage with size of 40X40X40 cm3. It is closed, the four side of cage walls are all with mesh for aeration. For one fly, its minimum active range is 10 cm3, so 3000 couple of flies can be reared in one cage.

In this cage, 13~15 gram eggs can be laid every day.(600 eggs can be laid by one couple flies within 10 days, one gram eggs contain 12000-14000 eggs, so 3000 couple flies can lay 13~15 gram per day). It is enough for food source needs of 9~10 crew every day. (one crew need 1.5 gram fly eggs as the daily food source)

2, Feedstuff:

The feedstuff of ovipositing HF is required better than that of HFL, because HF likes eating HFL paste (smash live HFL into paste), and fortunately, the HFL paste could be easily self-sufficient in space. The formula of the feedstuff for HF in space contains:70% of HFL paste and 30% of wheat bran or bean dregs.:

3, Approach of rearing FL in space:

Rearing HFL is the same as the above mentioned. Before HFL reach mature, usually they take 4 day of rearing. The HFL are all in the lower layer of the rearing container with wood bits for pupating, temperature within 24~32^{0}C, humidity 60~~70%, kept in dark and aeration speed of 0.5~1.0 grade. Choose the pupa whose weight is more than 18 mg as the seed. Pupa will have eclosion after 5-7days, while HF can oviposit 3 days after eclosion and ovipositing period is 30 days or so. As a rule, HF will be killed after 15 days ovipositing and stop getting eggs for assuring the egg quality.

Rearing temperature in HF rearing cage is 28~30^{0}C, humidity is 60~70%. The feedstuff for rearing HFL is supplied with a small feedstuff box in the cage, including absorbed water sponge, feedstuff sponge and lured ovipositing sponge (the sponge absorbs water and feedstuff to prevent the water and feedstuff from floating off under the microgravity). In addition to fresh human faces as ovipositing lured matter paste on, the feedstuff is the same to be applied on the lured ovipositing sponge, which can be put into 3 days after eclosion of pupa, at intervals of 12 hours. These three sponges should be alternated and the HF eggs could be collected once every morning and afternoon. The rearing cage needs to be sterilized with ultraviolet ray before rearing, HF pupa comes to eclosion after being disinfected by using potassium permanganate.

Rearing HF needs lighting, the longer time of lighting , more benefit for FL growth and ovipositing.

Processing of HFL powder

1) Steps: Collecting Fresh HFL→Cleaning→Drying→Grinding→bactericidal procedure→Collecting powder→Package→Storage
2) Drying: Microwave under 80^{0}C
3) Drying within 6 hours after collecting HFL to prevent fresh HFL from becoming pupa.
4) The HFL powder can be stored in freeze for long term preservation.

Application of HFL as feedstuff for animals:

Due to the rich protein and other nutrition HFL contain, applying HFL as feedstuff offers good animal protein and other rich nutrients to poultry, livestock and aquatics to achieve large rate of reproduction and survive. It was proved by many countries in the world.[1][2][3][4][5][6][7][10][12][19][20].

As the intake ratio of hens fed by feedstuffs is about 30%, a great deal of nutrition are left in the hen's manure. HFL can recycle the nutrition from manure. Experiment points, the HFL were reared by manure from three hens, It can meet the nutrition demand of two hens [22]. Thus only one hen's feedstuff can sustain three hens. This is the best proven example for HFL fed by manure. The method can not only save feedstuffs, but also assure of good health.

Feeding Animals by HFL in the space:

The proportionate nutrients of HFL powder are of free of pathogens and toxicity with quite mild taste. From its nutritive value and special health-keeping function, it should be ideal food for human in space. This is the most simple food chain in recycling of the waste in space. But in fact, people's cultural barriers and eating habits make themselves rather difficult to accept insect as food, not to say HFL, the dirty insects with human waste as their food, in such an inclement environment of space. Therefore, in our design, the first key step we have to complete is to convert all the wastes from human, animals and space crop efficiently into HFL. The second step is to take HFL as animal feedstuff. These animals and their eggs are looked upon as human food. In this way, the HFL and animals will be the medium loops between the human food and wastes. Their function is to recycle wastes to be human food. Thus, a closed food chain, food to waste to food can be completed with HFL and feeding animals. The embarrassment of taking HFL as the human diet can be avoided. HFL as the animal food and animals as the human food can be easily acceptable.

The animals of poultry, aquatics, amphibian and livestock are successfully fed by maggot both in farms and labs.[1]~[13].

In this invention, we recommend the partridge, tilapia and America bullfrog as the first candidates for space testing animals, (the swine may be the future candidate). The reason to choose the above-mentioned three kinds of animals as the space feeding animals is, that they have common grounds as follows:

(1) **Their feedstuff all can be self-sufficient in the space.** The delighted feedstuff of all of them is living HFL and HFL powder, and other accessorial feedstuff is inedible crop (wheat bran, bean dreg and so on), these animals puerile stage, can all be fed with HFL power adding inedible crop, then can be fed with adding living HFL after they grow up.

(2) **These animals are successfully fed on the earth by feeding maggot who convert the nutrients from animal waste.** These feeding tests utilized chicks[12],pigs[6], Catfish and tilapia [7][8], frogs [12], and the partridge (We just done in June of 2003)

(3) **They all had primary space hatching and feeding experiments, though these experiments are merely zoology experiments under microgravity, whose aim is not to feed them as food. However, they also demonstrate that feeding them in the space is feasible:**

In February,1999, 37 little partridges have been hatched out from 60 partridge eggs by the crew in Russian Peace ISS. Even though in the bad environment of strong radiant of the space, yet 10 were alive. Embryology study of South African Frog in US STS-47 Space Shuttle shows the eggs laid by the frog in the space. Those eggs were all hatched out to little polliwogs. Experiments with fish and spawn are made successfully as well.

Another significant advantage of feeding aquatic animals is that they originally live in the water which is similar to the microgravity environment of the space. Therefore, their zoology in the space, especially taking food and reproduction in water, will be the same as on the earth and not affected by microgravity. FHL can survive for over 24 to 48 hours on the water surface[20]. So it is convenient for the aquatic animals to eat active FHL in the water as on the globe.

The water is basic source for survival of humans and animals in space. Fortunately, there is information indicating apparent presence of ice in permanently shaded area at the south pole of the Moon. Also water is known to exist on the polar ice caps and below the surface of the Mars. Once these water resource can be exploited, it is easily to rear varied aquatic animals in large scale by feeding maggot on these planets.

(4) **The eggs of these animals can be brought from earth and be stored in liquid nitrogen for long term cryopreservation,** just the same as the fly eggs, then can be hatched after re-warm. However, they can reproduce by themselves in the space.

(5) **These animals have small size body, fast growth and short mature term, high rate of oviposition, can be densely reared, are strong in anti-illness and adaptation.** Its meat is all high protein food with low fat and low cholesterin, easy for digesting with good taste. As for example of partridge, its ovipositing term will be 35-45 days after hatching. The rate of oviposition is higher then 80%, weight rate of egg/body is 2.5~2.7 times higher than that of chicken. Small capacity of diet, the weight rate of diet/egg is 3. Prefer to eat maggot. The maggot prefers to eat the partridge manure. In our 60 partridge feeding test with HFL, the daily manure of two adult men and 60 partridges, with adding 10% manure weight of

wheat bran as the feedstuff for rearing HFL from 2.5 gram of HF eggs, can harvest around 600 g fresh HFL every day. The partridge average weight increases 13% by feeding daily diet with living HFL (10 g HFL +25 g normal feedstuff) compared with control group with normal diet (40g normal feedstuff) within 27 days feeding period. Same as the tilapia, its mature term is very short, can be token as food after hatching 2~3 months, can oviposit and hatching by themselves with high rate while being fed in closed water tank without much care.

(6) The technologies for rearing these animals on the ground are mature and well known.

The safety of the HFL and HFL powder:

(1) Pathogen free of the HFL and HFL powder:

HFL has special immunity ability for resisting bacteria. Their body contains many kinds of active protein for resisting bacteria greatly. That is far greater than penicillin [22].

Bacteriological interactions associated with manure digestion by maggots are favorable. Maggots are competitors with bacteria for nutrients and often reduce bacterial numbers, to eliminate them altogether. Maggot may consume and digest microorganism, and produce antibacterial and/or fungicidal compounds. Numerous studies using dried, rendered and fresh maggot as animal feed have revealed no health problems resulting from this practice. Culturing of self-collected soldier fly prepupae from a recent swine trail revealed no pathogen .[12].

Reference [17] pointed, assays on 100g HFL powder from above mentioned processing steps, colic bacillus and pathogen are all free, the total bacteria number is lower than standard milk powder. It shows that this HFL powder as human food is edible.

To assume of rearing FHL in space, the eggs are from cryopreservation; the feedstuff and rearing containers can be disinfected in advance; the processing of the HFL powder is under bactericidal procedure. So the HFL and HFL powder can be assumed pathogen free.

(2) Without poison:

References[16][17][18][22]offer data for analysing ingredients of HFL powder and prove HFL powder is rich protein food without any poison.

Ideal fertilizer for space crop--the residues after rearing HFL:

In our experiment, the wastes (35% fresh human dejection+55% partridge manure and+10% wheat bran) were Digested by HFL so fast. The odor from the waste is almost free after one day rearing. The residual waste is

Reduced 57% after 3 days rearing.

Miller etc.[2] reported, after HFL digesting of the hen manure, the residue still contains 15% protein. It can be used as the good soil improving agent or fertilizer。 80% organism material of the hen manure is converted by HFL, loses about half of moisture, dry matter and total weight at the same time, but only the ash keeps same,

Teotia etc.[3] reported, after HFL digesting of the hen manure, the residue contains 17.62 protein, nitrogen reduction from 7.5% to 2.6%,the phosphorus reduction from 3.4% to 1.8%. Sheppard reported [10][9], that their manure management system using black soldier fly can reduces residual manure by 50%, including a 24% reduction in nitrogen concentration within this 50% residual manure, resulting in total nitrogen reduction of 62%. More recently, he suggested higher rate of nitrogen removal is possible, as is a significant reduction in phosphorus. It is evident that nitrogen and phosphorous removal as maggot biomass will be a significant benefit in nutrient management.

The Moscow Biology Medical Research Institute reported, the manure residues after HFL digesting, is a kind of humic matter with no infective pathogen. Use it as fertilizer for tomato, cucumber, black mushrooms etc., can get the high rate of production and good quality [20]. Morgan& Eby [5] reported, using HFL can convert 100 Kg of fresh hen manure or cow manure to 2~3Kg protein feedstuff, can also produce 50~60 kg dry and odorless soil improving agent. As maggots can reduce pathogens in human/animal waste, they may make it safer for organic vegetable production.[12]

The other function of maggot powder:

Due to lack of protection of earth aerosphere and magnetic field in space, there are obvious harms on the human body by varied strong space radiation while human living in the space, such as the reduction of the white cell and immune cell, causing cancer and hurt of the fertility ability etc. To resist of the harms from space radiation is the important research program in NASA and many countries in the world, but there is no effective way yet.

The tests have proved, taking the maggot powder as healthy food, can improve the ability of resisting radiation and immune function whether for animals or human body. For the patients under treatment of radiation or chemical, the reduction of white cells and immune cells obviously slows down, the hair lost is apparently decreasing. It is not sure what is the effective ingredient for these functions in maggot body, but there is a quite important clinical signification for human living in the space or on the earth.. The crop or animal internal organs could be feedstuff for rearing maggot on the earth or in the space, some herbal

medicine and other ingredients with special function can be added in those feedstuff, or into maggot (pupa) powder for increasing effect. It can be taken by the people who have to touch with the radiation or live in the place where is polluted by radiation. Furthermore, the animals feeding by the maggot, their meat and eggs can have the similar function too. The daily dose for adult is 0.3~1.0 gram of pure maggot (pupa) powder

Maggot can be carrier for some special ingredients by feeding with relevant ingredient that human need, such as vitamins, minerals, electrolytes and antibiotic etc., so the rearing animals will be the carrier for these relevant ingredients too by feeding with those maggot.

Russia and Korea has exploited maggot carrier, for example, maggot can contain enough antibiotic and trace element by rearing maggot with relevant ingredient[20].

Merits of rearing maggot in long term mission

1. Recycle fully wastes of human/animals and inedible crop in space by rearing maggot which will be nourishing feedstuff for feeding animals, the animals and crop will be human food, it would achieve a food regenerative system with close loops in space.
2. Maggot is a ideal food source for offering many kinds of nutrition such as rich protein, fatty acid, amino acids, vitamins, minerals, electrolytes and many unknown nutrients. Combined with the animals fed by maggot and crop, they can meet the most needs of nutrition for human in long term space mission.
3, With the storage technology of frozen fly eggs and animal eggs, oosperm and placenta, they can be frozen in liquid nitrogen for cryopreservation, could achieve safe and sufficient food source and food ingredient storage in long term mission.
4, Maggot and feeding animals all have strong reproduction ability, short cycle and high speed of growth.. It is easy to rear continuously day and night in high density to achieve the efficient and self-sufficient food production.
5, Maggots seldom get disease. Rearing maggot and processing of the maggot powder are all pathogens free and chemicals free. Using it to feed animals for human foods is safe, and does not produce harmful substance to pollute environment.
6, Rearing maggot and animals are all well developed technology which can be easily transferred to space application with less research investment and time. To rear them only needs simple production equipment, operation and technique. The food production, processing and storage are all with little space, so that the cost of food production, processing, storage and waste recycling could be minimized.